THE MAINTENANCE OF FERTILITY

FIELD EXPERIMENTS WITH FERTILIZERS AND MANURES ON TOBACCO, CORN, WHEAT AND CLOVER IN THE MIAMI VALLEY.

OHIO
Agricultural Experiment Station.

WOOSTER, OHIO, U. S. A., AUGUST, 1909.

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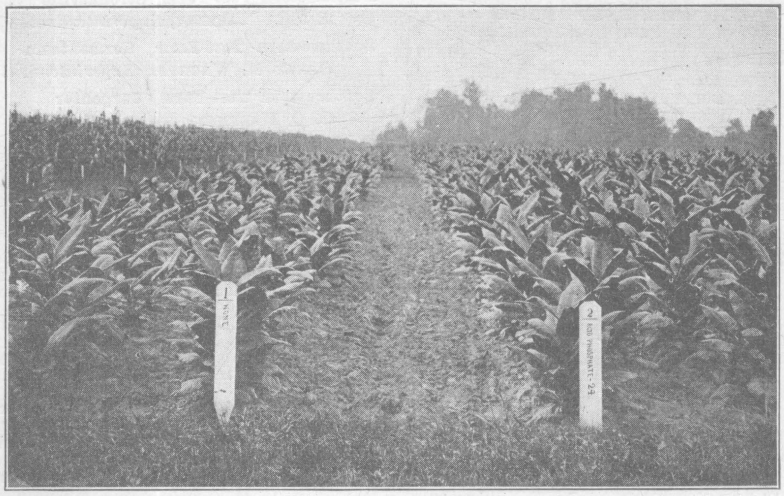

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BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 206. AUGUST, 1909

EXPERIMENTS WITH FERTILIZERS AND MANURE ON TOBACCO, CORN, WHEAT AND CLOVER IN THE MIAMI VALLEY

These experiments were begun in 1903 on tobacco, grown both continuously and in rotation with wheat and clover, and in 1904 and 1905 on corn and wheat, grown in a rotation of corn, wheat and clover. A description of the soil and the plan of the experiments with tobacco are given in Bulletin 161 of this Station, and a continuation of the work with tobacco up to 1905 is reported in Bulletin 172. The rotation of corn, wheat and clover is in part reported in Bulletin 182, and the statistics of all the crops up to 1906 are given in Bulletin 184.

I: FERTILIZERS AND MANURE ON TOBACCO GROWN IN ROTATION

The plan of fertilizing in the rotation of tobacco, wheat and clover is given in Table I and Diagrams I and II; the statistics of yield for the years 1907 and 1908 are given in Table II, and a general summary of the results for the entire period is given in Table III, in which the yields of tobacco are grouped in two 3-year periods, thus showing the cumulative effect of the fertilizers during the second period.

DIAGRAM I: ARRANGEMENT OF PLOTS IN TOBACCO-WHEAT-CLOVER ROTATION

Section A

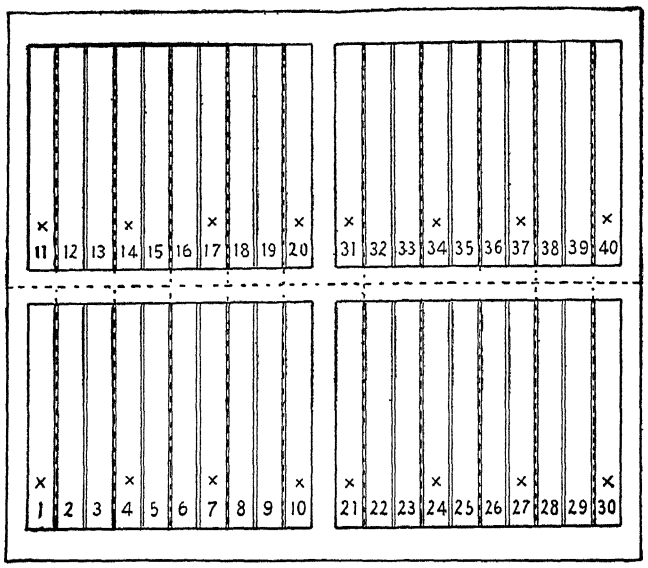


TABLE I: PLAN OF FERTILIZING TOBACCO GROWN IN ROTATION.

Plot No.	Fertilizing materials per acre (All applied to the tobacco crop)	Fertilizing elements per acre.		
		Phosphorus	Potassium	Nitrogen
		Lbs.	Lbs.	Lb
1	None	..	..	..
2	Acid phosphate, 480 lbs.	30	..	..
3	Acid phosphate, 480 lbs.; muriate potash, 180 lbs.	30	75	..
4	None	..	..	..
5	Muriate potash, 180 lbs.; nitrate soda, 240 lbs.	..	75	38
6	Acid phosphate, 480 lbs.; nitrate soda, 240 lbs.	30	..	38
7	None	..	..	..
8	Acid phos., 480 lbs.; mur. potash, 180 lbs.; nit. soda, 240 lbs.	30	75	38
9	Acid phos., 480 lbs.; mur. potash, 300 lbs.; nit. soda, 240 lbs.	30	125	38
10	None	..	..	..
11	None	..	..	..
12	Acid phos., 480 lbs.; mur. potash, 120 lbs.; nit. soda, 240 lbs.	30	50	38
13	Acid phos., 720 lbs.; mur. potash, 180 lbs.; nit. soda, 240 lbs.	45	75	38
14	None	..	..	..
15	Acid phos., 480 lbs.; mur. potash, 180 lbs.; nit. soda, 360 lbs.	30	75	57
16	Acid phos., 480 lbs.; mur. potash, 180 lbs.; sulph. ammonia, 180 lbs.	30	75	38
17	None	..	..	..
18	Acid phos., 60 lbs.; Tankage (7-20) 670 lbs.; muriate potash, 180 lbs.	30	75	38
19	Acid phos., 320 lbs.; mur. potash, 180 lbs.; nit. soda, 240 lbs.	20	75	38
20	None	..	..	..
21	None	..	..	..
22	Acid phos., 480 lbs.; nitrate potash, 200 lbs.; nit. soda, 80 lbs.	30	75	38
23	Acid phos., 480 lbs.; sulphate potash, 190 lbs.; nit. soda, 240 lbs.	30	75	38
24	None	..	..	..
25	Acid phos., 480 lbs.; sul. potash, 190 lbs., nit. soda, 240 lbs.; lime 1000 lbs.	30	75	38
26	Acid phos., 480 lbs.; mur. potash, 180 lbs.; nit soda, 240 lbs.; lime 1000 lbs.	30	75	38
27	None	..	..	..
28	Acid phos., 480 lbs.; mur. potash, 180 lbs.; sul. am., 180 lbs.; lime 1000 lbs.	30	75	38
29	Acid phos., 60 lbs.; tankage (7-20) 670 lbs.; mur. pot., 180 lbs.; lime 1000 lbs	30	75	38
30	None	..	..	..
31	None	..	..	..
32	Shed manure, untreated, 10 tons	..	..	..
33	Shed manure, untreated, 20 tons	..	..	..
34	None	..	..	..
35	Shed manure, phosphated, 10 tons	..	..	..
36	Yard manure, phosphated, 10 tons	..	..	..
37	None	..	..	..
38	Shed manure, untreated, 10 tons; lime, 1000 lbs.	..	..	..
39	Yard manure, untreated, 10 tons; lime, 1000 lbs.	..	..	..
40	None	..	..	..

The plots employed in this test are 16 feet wide by 136 feet long, containing one-twentieth acre each. They are separated by paths two feet wide and tile drains are laid under alternate paths, making the drains 36 feet apart. The plots are arranged in blocks of ten plots each and in three sections, A, B and C, of 40 plots each, as indicated by the diagrams, and every third plot is left continuously untreated. The increase due to treatment is calculated on the assumption that if Plots 1 and 4, untreated, were to yield 300 and 330 pounds respectively, the unaided yields of Plots 2 and 3 would probably have been 310 and 320 pounds.

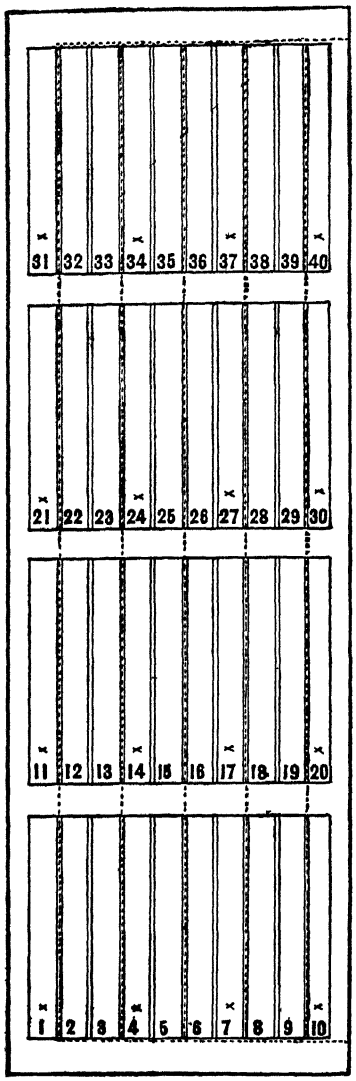


DIAGRAM II: Arrangement of plots in tobacco-wheat-clover rotation. Sections B and C.

Section A is located on a small farm of 13 acres, which had been owned separately from the tract on which B and C are located before the land was leased by the Experiment Station.

In Table IV is given the average increase per acre for each crop over the entire period of the experiment with its value, rating tobacco at eight cents per pound for the wrapper and filler and one and one-half cent for the trash; wheat at 80 cents per bushel; straw at $2.00 per ton, and hay at $8.00. This table also shows the cost of the fertilizing, rating 14 percent acid phosphate at $16.00 per ton; muriate of potash at two and one-half cents per pound, and nitrate of soda at three cents, and estimating the cost of potassium in the sulphate as 20 percent greater than in the muriate. The cost of nitrogen is assumed to be the same in nitrate of soda, nitrate of potash and sulphate of ammonia. The tankage used in the test is computed at $28.00 per ton. Lime is figured at $6.00 per ton. No values are placed upon the manure, as the cost of manure varies for each farm and for different parts of the same farm, owing to the distance from the barn. The phosphated manure has been dusted with floats applied at the rate of 40 to 50 pounds per ton of manure, equivalent to one pound per 1000-pound animal per day.

TABLE II: TOBACCO-WHEAT-CLOVER ROTATION. STATISTICS OF YIELD FOR 1907 AND 1908

Plot	Tobacco						Wheat				Clover hay	
	1907			1908			1907		1908			
	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Grain	Straw	Grain	Straw	1907	1908
No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bus.	Lbs.	Bus.	Lbs.	Lbs.	Lbs.
1	605	140	745	395	150	545	19.78	2,133	9.67	2,000	2,480	3,000
2	970	180	1,150	640	200	840	22.29	2,403	17.75	3,755	2,760	4,460
3	1,230	150	1,380	1,020	180	1,200	24.43	2,634	22 67	3,760	3,520	5,080
4	550	150	700	430	130	560	22.29	2,403	9.83	2,190	2,260	2,520
5	970	130	1,100	580	140	720	29.44	3,175	12.50	2,430	2,940	3,240
6	1,300	180	1,480	835	190	1,025	26.93	2,904	20.42	3,835	3,100	4,460
7	655	120	775	470	170	640	19.55	2,107	12 08	2,315	2,500	2,640
8	1,460	120	1,580	1,185	210	1,395	26 22	2,827	22.50	3,350	3,260	5,020
9	1,380	160	1,540	1,090	170	1,260	26.93	2,904	22 58	3,225	3,360	5,120
10	480	145	625	505	140	645	19.43	2,095	10 50	1,990	2,860	2,500
11	425	135	560	440	140	580	21.09	2,275	9 33	1,760	3,400	2,920
12	1,205	140	1,345	1,170	140	1,310	27.05	2,917	24 25	3,985	3,440	4,980
13	1,425	120	1,545	1,240	170	1,410	30 27	3,264	28 58	4,285	3,900	6,020
14	360	125	485	380	130	510	23.12	2,493	10.75	1,915	2,400	3,340
15	1,250	130	1,380	1,095	160	1,255	30.87	3,328	27.58	4,045	2,700	5,480
16	1,135	140	1,275	1,050	140	1,190	28.72	3,096	27 00	3,960	2,440	5,620
17	355	120	475	330	130	460	23 24	2,505	9 50	1,830	1,620	3,360
18	1,100	120	1,220	885	170	1,055	30.75	3,315	26.58	3,765	2,580	4,640
19	1,060	130	1,190	1,020	160	1,180	27.18	2,930	25 67	3,720	2,760	4,500
20	275	100	375	390	155	545	20.26	2,185	7 75	1,435	2,380	3,060
21	465	140	605	460	140	600	16.69	1,800	8 83	1,490	3,220	2,240
22	1,170	150	1,320	1,070	190	1,260	25.86	2,788	21.42	3,595	3,140	4,440
23	1,190	170	1,360	1,095	185	1,280	26.46	2,852	20 92	3,385	3,660	4,440
24	340	120	460	615	170	785	18.23	1,966	6 50	1,150	2,680	2,200
25	1,100	160	1,260	1,070	160	1,230	26.22	2,827	22.92	3,445	3,700	4,180
26	1,195	145	1,340	1,120	180	1,300	27.53	2,968	24.17	3,630	3,740	4,160
27	375	135	510	485	150	635	17.88	1,927	7.25	1,365	2,620	1,980
28	1,120	160	1,280	1,155	110	1,265	24.91	2,685	24 50	3,530	3,700	4,680
29	1,175	150	1,325	930	160	1,090	27.16	2,930	19 92	2,865	3,620	4,400
30	550	160	710	385	150	535	17.04	1,838	10.00	1,700	2,140	2,060
31	680	120	800	330	120	450	15.61	1,683	10.50	1,670	2,240	1,700
32	1,130	120	1,250	720	130	850	29.08	3,135	16 92	2,905	2,680	3,420
33	1,340	170	1,510	915	170	1,085	37.31	4,022	22.33	3,460	3,460	5,040
34	550	130	680	350	140	490	18.71	2,017	6.33	1,060	2,580	2,280
35	1,135	125	1,260	840	155	995	27.18	2,930	23.42	3,575	3,340	5,040
36	1,120	120	1,240	620	140	760	30.75	3,315	21.08	3,335	2,620	4,380
37	470	140	610	380	120	500	17.16	1,850	6.67	1,540	2,260	1,960
38	930	110	1,040	590	150	740	27.89	3,006	16.75	3,195	2,760	3,380
39	540	120	660	500	150	650	29.80	3,212	13.08	2,415	2,240	3,660
40	365	130	495	300	115	415	18.24	1,966	8.33	1,640	1,540	1,780
*	469	132	601	414	140	554	19.27	2 077	8.99	1 691	2 449	2 471

* Average unfertilized yield.

TABLE III: TOBACCO-WHEATrCLOVER ROTATION: AVERAGE YIELDS BY PERIODS.

Plot	Tobacco									Wheat		Clover	Plot
	First rotation—1903-5			Second rotation—1906-8			6-year average, 1903-8			5-year average, 1904-8		4-year average	
	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Grain	Straw	1905-1908	
No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bus.	Lbs.	Lbs.	No.
1	500	136	636	497	163	660	498	150	648	12.08	1,694	2,585	1
2	650	187	837	807	208	1,015	728	198	926	18.45	2,560	3,335	2
3	917	160	1,077	1,110	177	1,287	1 013	169	1,182	20.63	2,743	3,910	3
4	450	157	607	493	154	647	471	156	627	11.72	1,622	2,370	4
5	787	130	917	770	167	937	778	149	927	18.46	2,249	3,190	5
6	907	190	1,097	1,092	196	1,288	999	193	1,192	22.89	2,926	4,020	6
7	510	157	667	568	163	732	539	160	699	13.38	1,741	2,485	7
8	983	133	1,117	1,298	177	1,475	1,141	155	1,296	28.42	2,899	4,160	8
9	968	157	1,125	1,190	223	1,413	1,079	190	1,269	23.58	2,749	4,305	9
10	423	140	563	502	168	670	462	154	616	12.70	1,598	2,195	10
11	388	117	505	457	168	625	422	143	565	12 95	1,639	2,750	11
12	857	170	1,027	1,198	160	1,358	1,027	165	1,192	23.98	2,949	3,875	12
13	972	197	1,170	1,337	167	1,503	1,154	182	1,336	27.04	3,178	4,745	13
14	397	127	523	457	138	595	427	132	559	12.04	1,585	2,425	14
15	1,010	150	1,160	1,252	147	1,398	1,131	148	1,279	26.27	3,011	4,055	15
16	963	150	1,113	1,185	163	1,348	1,074	157	1,231	23.83	2,798	3,885	16
17	347	123	470	442	157	598	394	140	534	11.35	1,507	2,515	17
18	647	113	760	995	180	1,175	821	147	968	24.21	2,747	3,995	18
19	773	127	900	1,100	177	1,277	936	152	1,088	24.26	2,778	3,860	19
20	287	120	407	430	158	588	358	139	497	10.43	1,278	2,470	20
21	454	138	592	463	147	610	458	143	601	11.13	1,388	2,465	21
22	850	163	1,013	1,067	210	1,277	958	127	1,145	22.80	2,820	3,615	22
23	870	170	1,040	1,112	187	1,298	991	178	1,169	22.65	2,689	3,780	23
24	440	127	567	508	143	652	474	135	609	10.24	1,229	2,050	24
25	913	153	1,067	1,104	177	1,283	1,010	165	1,175	22.98	2,645	3,435	25
26	904	133	1,037	1,182	188	1,370	1,042	161	1,203	23.51	2,701	3,560	26
27	383	137	520	477	148	625	430	142	572	10.90	1,302	1,865	27
28	873	134	1,007	1,162	177	1,338	1,017	155	1,172	24.18	2,690	3,680	28
29	693	120	813	1,093	177	1,270	893	149	1,042	19 67	2,232	3,710	29
30	320	113	433	458	143	601	389	128	517	11.27	1,336	1,800	30
31	404	116	519	537	133	670	470	125	595	10.53	1,296	1,845	31
32	793	113	907	993	137	1,130	893	125	1,018	21.88	2,691	3,185	32
33	753	133	887	1,218	167	1,385	985	150	1,136	26.27	3,112	3,995	33
34	357	133	490	500	140	640	428	137	565	10.42	1,227	2,055	34
35	747	140	887	1,040	160	1,200	893	150	1,043	23.10	2,662	3,940	35
36	787	113	900	1,003	137	1,140	895	125	1,020	22.72	2,749	3,655	36
37	330	113	443	480	133	613	405	123	528	9.91	1,325	1,875	37
38	750	123	873	925	137	1,062	837	130	967	21.16	2,586	3,035	38
39	803	133	937	773	150	923	788	142	930	19.01	2,287	3 180	39
40	300	117	417	437	142	578	368	129	497	8.98	1,152	1,620	40
*	393	129	522	482	149	631	437	139	576	11.25	1,432	2,211	

* Average unfertilized yield.

The fertilizers and manures are all applied to the tobacco, the wheat and clover following without any treatment.

Comparing the increase on the first five fertilized plots, as given in Table IV, we find that each application of fertilizers has produced a profitable increase of crop, but the gain from the complete fertilizer, as applied on Plot 8, carrying nitrogen, phosphorus and potassium, all three, has been so much greater than that from any partial fertilizer, as to more than offset the greatly increased cost, so that the largest net gain has resulted from this application.

When the potassium in this fertilizer is increased, on Plot 9, the total tobacco yield remains the same, while that of wheat and hay are slightly increased; but while the total tobacco yield is stationary, there appears to have been a small transfer from the valuable parts of the plant to those less valuable and the consequence is a slight reduction in the total value of the output, and of course a greater one in the net value.

On the other hand, the reduction of the potassium, on Plot 12, results in a falling off in yield sufficient to more than neutralize the saving in the cost of the fertilizer, and a still greater loss occurs when it is entirely omitted, on Plot 6.

When sulphate of potash is substituted for the muriate, on Plot 23, there is a reduction in yield, as compared with Plot 8; and as the sulphate is more expensive than the muriate there is a still greater reduction in the net gain.

This comparison of sulphate with muriate of potash is repeated on two limed plots, numbers 25 and 26, and here again the sulphate falls behind the muriate in total yield and net gain, the loss being chiefly in the tobacco, as the wheat shows a small gain.

The substitution of the nitrate of potash, on Plot 22, has been followed by a still greater reduction in yield.

When the phosphorus is increased, on Plot 13, there is a marked gain in yield, this plot producing a greater total yield and a greater net gain than any other one in the series; while the reduction of the phosphorus, on Plot 19, is followed by a reduction in net gain as well as in total yield.

The increase of the nitrogen, on Plot 15, brings up the total yield to the second highest point in the series, and notwithstanding the high cost of nitrogen in nitrate of soda, this plot also gives next to the highest net gain. Comparing Plot 3, which receives phosphorus and potassium, but no nitrogen, with Plots 8 and 15, which receive the same quantities of phosphorus and potassium, in the

same carriers, reinforced with 240 pounds of nitrate of soda on Plot 8 and 360 pounds on Plot 15, it will be seen that the total gain is increased from $56.82 on Plot 3 to $66.62 on Plot 8 and $76.75 on Plot 15.

Comparing nitrate of soda with sulphate of ammonia as carriers of nitrogen, on Plots 8 and 16, and again with lime, on Plots 26 and 28, there is an apparent gain for the sulphate of ammonia in each case.

When nitrogen and phosphorus are given in tankage, on Plots 18 and 29, there is so great a reduction in the yield of tobacco as to much more than offset the small saving in the cost of the fertilizer. As tankage is the carrier of nitrogen usually employed in ready-mixed fertilizers this becomes an important point, the more so as the farmer generally pays more for the pound of nitrogen in such fertilizers than he would need to pay in nitrate of soda.

The manure used in this experiment for the first rotatation was horse manure; since then it has come from cattle, but in both cases it has accumulated on earth floors. Theoretically, ten tons of such manure should contain, when unleached, 75 to 80 pounds each of nitrogen and potassium and 25 to 30 of phosphorus. On this basis the constituents of the manure have not been quite as effective, pound for pound, as the same constituents in the chemical fertilizer. It will be observed, however, that when the manure has been used at the rate of 10 tons per acre it has produced increase to the average value of more than $5.00 per ton of manure.

Comparing Plots 32 and 35 it appears that the reinforcement of the manure with phosphorus (in the form of floats, and at the rate of approximately 40 pounds to the ton of manure) has materially increased its effectiveness. When thus treated there has been no practical difference in the effect of the yard and shed manure, but when both kinds of manure, untreated, have been followed by lime there has been a considerable superiority in the unleached manure.

EFFECT OF LIME.

The effect of lime is shown in Table V, in which are contrasted the yields of 5 pairs of plots, which are treated alike in all respects except the use of lime. Apparently lime is not yet needed on this soil for the crops grown in this experiment, the soil being chiefly derived from decomposition of limestone and limestone gravels.

TABLE IV: TOBACCO-WHEAT-CLOVER ROTATION. AVERAGE INCREASE, COST OF FERTILIZER AND NET GAIN PER ACRE.

Plot	Fertilizing elements per acre			Average increase per acre						Cost of fertilizers	Total value of Increase	Net gain	Plot
				Tobacco, 6-year average			Wheat, 5-yr. average		Clover 4-year Average				
	Phosphorus	Potassium	Nitrogen	Wrapper and filler	Trash	Total	Grain	Straw					
No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Bus.	Lbs.	Lbs.	$	$	$	No.
2	30	..		239	46	285	6.48	890	821	3 90	29.17	26.27	2
3	30	75	..	532	16	548	8 81	1,097	1,470	8.40	56.82	48.42	3
5	..	75	38	284	—7	277	6.20	587	782	11.70	31.29	19.59	5
6	30	..	38	482	35	517	10.06	1,224	1,573	9.10	54.64	45.54	6
8	30	75	38	627	—3	624	10.26	1,205	1,772	15.60	66.62	51.02	8
9	30	125	38	591	34	625	10.65	1,104	2,012	18.60	65.46	46.86	9
12	30	50	38	604	26	630	11.33	1,328	1,233	14.10	64.03	49.93	12
13	45	75	38	731	46	777	14.69	1,574	2,212	17.55	81.34	63.79	13
15	30	75	57	714	14	728	14.46	1,452	1,600	19.20	76.75	57.55	15
16	30	75	38	669	19	688	12.25	1,265	1,400	15.60	70.46	54 86	16
18	30	75	38	438	7	445	13.17	1,316	1,495	13.90	52.97	39.07	18
19	20	75	38	567	12	579	13.52	1,423	1,375	14.30	63 28	48.98	19
22	30	75	38	494	47	541	11.97	1,485	1,288	15.60	56.43	40.83	22
23	30	75	38	522	41	563	12.11	1,406	1,592	16.50	59.83	43.33	23
25	30	75	38	550	28	578	12.52	1,387	1,446	19.50	62.00	42.50	25
26	30	75	38	597	21	618	12.83	1,424	1,633	18.60	66.39	47.79	26
28	30	75	38	601	17	618	13.16	1,377	1,837	18.60	67.58	48.98	28
29	30	75	38	490	16	506	8.52	907	1,888	16.90	54.71	37.81	29
32	..	..	..	437	—3	434	11.39	1,418	1,270	.....	50.52	.....	32
33	..	..	..	543	23	566	15.82	1,862	2,010	.....	66.34	.....	33
35	..	..	..	473	18	491	12.86	1,403	1,945	.....	57.58	.....	35
36	..	..	..	482	—3	479	12.64	1,457	1,720	.....	56.97	.....	36
38	..	..	..	443	5	448	11.56	1,319	1,242	.....	51.04	.....	38
39	..	..	..	409	15	424	9.73	1 079	1,475	.....	47.70	.....	39
Average unfertilized yield.....				437	139	576	11.25	1 432	2 046				

The formula which is thus far producing the greatest increase in this experiment, that used on Plot 13, is made up as follows:

Fertilizing material	Pounds of essential constituents		
	Ammonia Lbs.	Phosphoric acid Lbs.	Potash Lbs.
Nitrate of soda. 240 lbs.....	45	....	....
Acid phosphate, 720 lbs..... ...	....	100	....
Muriate of potash, 180 lbs	....	....	90
Total 1140 lbs.....	45	100	90
Percentage	4	9	8

The percentages of "ammonia", "phosphoric acid" and "potash" are given above for the convenience of those who are accustomed to the use of this method of reckoning, but it must not be expected that the ordinary ready-mixed fertilizers will produce results equal to those obtained from these materials, although their cost will usually be greater.

TABLE V: EFFECT OF LIME ON TOBACCO, WHEAT AND CLOVER, GROWN IN ROTATION

Plot	Treatment	Average increase per acre			Value of Increase	
		Tobacco	Wheat	Hay	Total	Net
No.		Lbs.	Bus.	Lbs.	$	$
8	Acid phosphate, muriate potash, nitrate soda.....	624	10.26	1,772	66.62	51.02
26	" " " " " " lime.	618	12.83	1,633	66.39	47.79
23	Acid phosphate, sulphate potash, nitrate soda.....	563	12 11	1,592	59.83	43.33
25	" " " " " " lime..	578	12.52	1,446	62.00	42.50
16	Acid phoshate, muriate potash, sulphate ammonia.	688	12.25	1,400	70.46	54.86
28	" " " " " " lime.	618	13.16	1,837	67.58	48.98
18	Tankage, muriate potash.....	445	13.17	1,495	52.97	39.07
29	" " " lime.....	506	8.52	1,888	54.71	37.81
32	Untreated shed manure.....	434	11.39	1,270	50.52	
38	" " " lime.....	443	11.56	1 242	51.04	

II. FERTILIZERS AND MANURE ON TOBACCO GROWN CONTINUOUSLY ON THE SAME LAND.

Following is the plan of fertilizing in this test, the quantities being pounds per acre:

Plot 1, None
" 2, Acid phosphate, 160 lbs; muriate potash, 60 lbs.; nitrate soda, 80 lbs.
" 3, " " 160 " " " 60 " " " 160 "
" 4, None
" 5, Acid phosphate, 160 lbs; muriate potash, 60 lbs.; nitrate soda, 320 lbs.
" 6, " " 160 " " " 60 " " " 480 "
" 7, None
" 8, Acid phosphate, 320 lbs; muriate potash, 60 lbs.; nitrate soda 320 lbs.
" 9, " " 320 " " " 120 " " " 320 "
" 10, None

Plots 11 to 18, inclusive, are cross dressed with untreated shed manure, 8 tons per acre. The following additional treatment is given:

Plot 11, None.
" 12, Acid phosphate, 160 lbs.
" 13, Acid phosphate, 160 lbs.; muriate potash, 60 lbs.; nitrate soda, 160 lbs.
" 14, None.
" 15, Acid phosphate, 160 lbs.; muriate potash, 60 lbs.; nitrate soda, 320 lbs.
" 16, Phosphated shed manure, 5 tons.
" 17, None.
" 18, Phosphated yard manure, 5 tons.

Table VI gives the statistics of this experiment for 1906, 1907, and 1908 (continuing the record from Bulletin 172) with averages by periods, and the results are summarized in Table VII.

The cost of fertilizers, value of increase and net gain are computed annually in Table VII, whereas they are computed for each rotation of 3 years in Table III. In Table VIII the results of similar treatment are compared for the two 3-year periods during which the experiment has been in progress. This table shows that under each similar method of treatment there has not only been a smaller yield in the tobacco grown continuously than in that grown in rotation, which indeed is to be expected, since the rotated tobacco gets larger applications of fertilizer and manure than that grown continously, but that the rotated tobacco has increased in yield during the second period, as compared with the first, whereas that grown continuously has fallen off in yield in every case except on Plot 2, and there the gain has been very small. Reference to Table VI will show that even on the very heavily fertilized and manured plots in the continuous culture there has been a reduction in yield during the second period, as compared with the first.

TABLE VI: STATISTICS OF PRODUCTION OF TOBACCO GROWN CONTINUOUSLY, 1903 TO 1908.

Yield per acre

Plot	1906			1907			1908			3-year average, 1903-5			3-year average, 1906-8			6-year average, 1903-8			Plot
	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total	
No.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	No.
1	380	220	600	190	100	290	225	150	375	355	130	485	265	157	422	311	143	453	1
2	850	220	1,070	560	140	700	650	130	780	663	150	813	687	163	850	675	157	832	2
3	980	200	1,180	545	140	685	575	150	725	763	147	910	700	163	863	732	155	887	3
4	420	180	600	235	120	355	210	120	330	317	163	480	288	140	428	302	152	454	4
5	1,030	240	1,270	730	150	880	740	140	880	806	167	973	833	177	1,010	820	172	992	5
6	1,125	220	1,345	745	140	885	680	140	820	763	164	927	850	167	1,017	807	165	972	6
7	280	170	450	165	95	260	145	135	280	303	120	423	197	133	330	250	127	377	7
8	1,160	220	1,380	820	160	980	805	130	935	837	193	1,030	928	170	1,098	882	182	1,064	8
9	1,330	180	1,510	880	150	1,030	875	150	1,025	963	147	1,110	1,028	160	1,188	996	153	1,149	9
10	240	120	360	140	90	230	165	140	305	210	110	320	182	117	299	196	113	309	10
*	330	172	502	182	101	283	186	136	322	296	131	427	233	137	370	265	134	399	
	Cross dressed with untreated manure, 8 tons per acre																		
11	850	130	980	500	140	640	595	125	720	760	280	1,040	648	132	780	738	159	897	11
12	955	170	1,125	725	155	880	760	155	915	720	350	1,070	813	160	973	803	183	986	12
13	1,280	180	1,460	940	180	1,120	850	150	1,000	1,050	260	1,310	945	160	1,105	1,006	172	1,178	13
14	1,070	140	1,210	540	140	680	615	120	735	990	160	1,150	742	133	875	809	137	946	14
15	1,350	140	1,490	1,020	150	1,170	940	110	1,050	1,320	230	1,550	1,103	133	1,236	1,100	152	1,252	15
16	1,400	130	1,530	1,025	150	1,175	1,040	110	1,150	1,230	220	1,450	1,155	130	1,285	1,121	145	1,266	16
17	1,160	200	1,360	830	160	990	865	135	1,000	940	370	1,310	952	165	1,117	909	189	1,098	17
18	1,290	180	1,470	1,160	140	1,300	1,010	135	1,145	1,120	260	1,380	1,153	152	1,305	1,103	161	1,264	18
**	1027	157	1,183	623	147	770	692	127	819	897	270	1,167	781	143	924	819	162	931	
	Increase per acre																		
2	457	13	470	355	33	388	430	—10	420	373	— 63	310	414	12	426	367	11	378	2
3	573	7	580	325	27	352	360	20	380	547	—107	440	419	18	437	427	6	433	3
5	656	64	720	518	38	556	551	15	566	690	— 40	650	575	39	614	535	28	563	5
6	799	47	846	557	37	594	514	10	524	560	.....	560	623	32	655	539	30	569	6
8	893	67	960	664	67	731	663	— 7	656	673	127	800	740	42	782	652	59	711	8
9	1,077	43	1,120	731	58	789	717	12	729	877	— 7	870	842	38	880	782	35	817	9
12	32	37	69	211	15	226	158	32	190	—113	110	—3	134	28	162	42	32	74	12
13	283	43	326	414	40	454	242	28	270	137	60	197	313	37	350	221	28	249	13
15	250	—20	230	383	3	386	242	—15	227	346	.....	346	891	—37	854	257	— 2	255	15
16	270	—50	220	292	— 3	289	258	—20	238	274	— 80	194	820	—73	747	245	—27	218	16
18	130	—20	110	330	—20	310	145	....	145	180	—110	70	202	—13	189	194	—28	166	18

* Average unfertilized yield.
** Average yield of plots receiving manure only, 8 tons per acre.

TABLE VII: TOBACCO GROWN CONTINUOUSLY: SUMMARY OF RESULTS FOR 6 YEARS.

Plot No.	Treatment	Cost of fertilizers	Value of Increase	Net gain
2	Acid phosphate, 160 lbs.; muriate potash, 60 lbs.; nitrate soda, 80 lbs.	$ 5.20	$ 29.52	$ 24.34
3	" " 160 " " " 60 " " " 160 "	7.60	34.45	26.85
5	" " 160 " " " 60 " " " 320 "	12.40	43.22	31.82
6	" " 160 " " " 60 " " " 480 "	17 20	43.57	26 37
8	" " 320 " " " 60 " " " 320 "	13.70	53 05	39.35
9	" " 320 " " " 120 " " " 320 "	15.20	63.08	47.88
11-14-17	8 tons manure	.....	44.74	.....
12	" " and 160 lbs., acid phosphate	1.30	48.58	.....
13	" " and same fertilizers as on Plot 2	7.60	62.94	.....
15	" " " " " " " " 3	12.40	65.27	.....
16	" " " 5 tons phosphated shed manure	1.30	63.94	.....
18	" " " " " yard "	1.30	59.74	.....

TABLE VIII: COMPARISON OF YIELDS OF TOBACCO PER ACRE IN CONTINUOUS AND ROTATIVE CROPPING.

Treatment			First period, 1903-5			Second period, 1906-8		
Fertilizers per acre per period	Cropping	Plot	Wrapper and filler	Trash	Total	Wrapper and filler	Trash	Total
		No.	Lbs.	Lbs.	Lbs	Lbs.	Lbs.	Lbs.
None	Rotative....	a	393	129	522	482	149	631
	Continuous..	b	296	131	427	253	137	370
Acid phosphate, 480 lbs.; muriate potash, 180 lbs.; nitrate soda, 240 lbs.	Rotative....	8	983	133	1,117	1,298	177	1,475
	Continuous..	2	663	150	813	687	163	850
Acid phos., 480 lbs.; mur. potash, 180 lbs.; nit. soda, 360 lbs.	Rotative....	15	1,010	150	1,160	1,252	147	1,398
" " 480 " " " 180 " " " 480 "	Continuous..	3	763	147	910	700	163	863
Untreated shed manure, 20 tons	Rotative....	33	753	133	887	1,218	167	1,385
" " " 24 "	Continuous..	c	897	270	1,167	781	143	924

a Average of all unfertilized plots.
b Average of Plots 1, 4, 7 and 10.
c Average of Plots 11, 14 and 17.

III. FERTILIZERS AND MANURE ON CORN AND WHEAT GROWN IN ROTATION WITH CLOVER.

The plan of this cereal rotation is shown in Table IX. The statistics for the first 3 years of the experiment, 1905 to 1906, inclusive , are given in Bulletin 184, and those for 1907 and 1908 follow in Table X, while Table XI is a summary of the results for the entire period of the experiment.

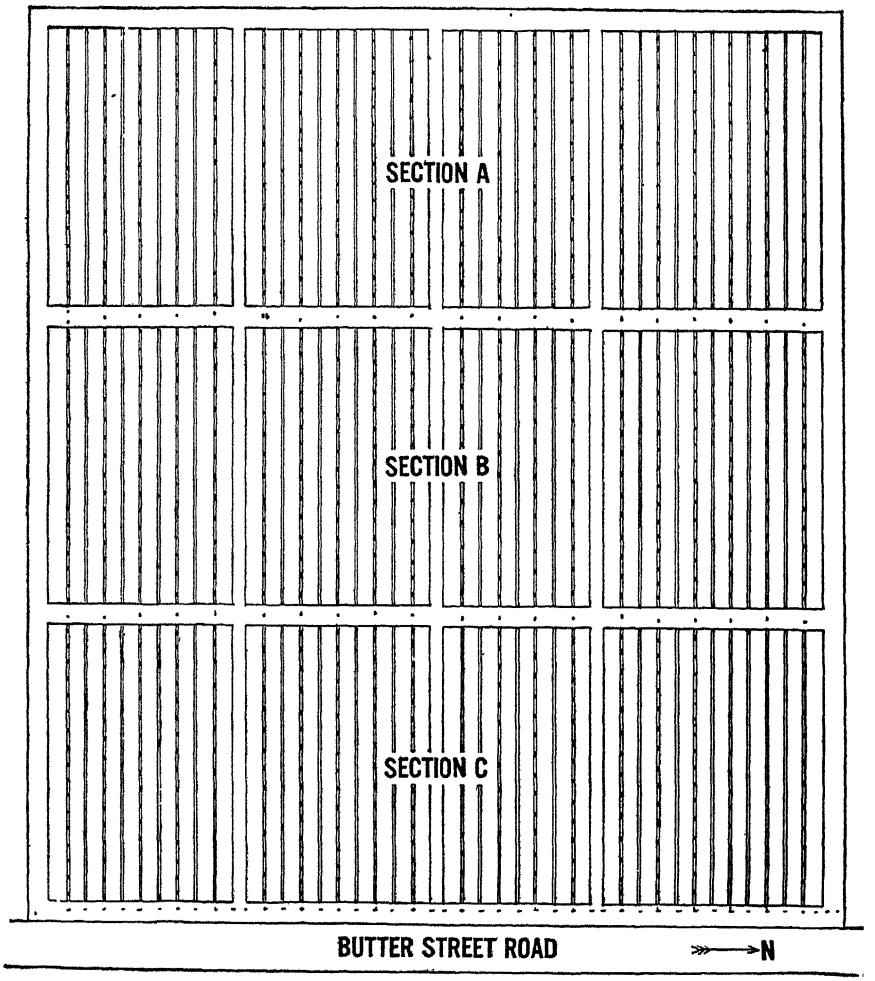
TABLE IX: PLAN OF FERTILIZING IN CORN-WHEAT-CLOVER ROTATION AT THE GERMANTOWN TEST-FARM.

Plot No.	Fertilizing materials—pounds per acre								Fertilizing elements—pounds per acre.		
	On corn			On Wheat							
	Acid phosphate	Muriate of potash	Nitrate of soda	Acid phosphate	Muriate of potash	Dried Blood	Nitrate of soda	Total fertilizers for one rotation	Phosphorus	Potassium	Nitrogen
1	....	....	...	....	....	....	....	....	....	....	....
2	120	....	....	120	....	....	....	240	15	....	....
3	120	20	....	120	20	....	....	280	15	16½	....
4	....	....	....	....	....	....	....	....	....	....	....
5	....	20	80	....	20	30	60	210	....	16½	25½
6	120	....	80	120	....	30	60	410	15	....	25½
7	....	....	....	....	....	....	....	....	....	....	....
8	120	20	80	120	20	30	60	450	15	16½	25½
9	120	20	160	120	20	30	140	610	15	16½	50⅔
10	....	....	....	....	....	....	....	....	....	....	....
11	120	40	160	120	40	30	140	650	15	33	25½
12	240	20	80	240	20	30	60	710	30	16½	25½
13	....	....	....	....	....	....	....	....	....	....	....
14	240	40	160	240	40	30	140	890	30	33	50⅔
15	480	80	320	Lime, 1,000 pounds				890	30	33	50⅔
16	....	....	....	....	....	....	....	....	....	....	....
17	Untreated shed manure 5 tons on corn; lime, 1,000 lbs. on wheat.										
18	Untreated shed manure 10 tons, 1904-5-6; lime, 1,000 lbs., 1907-8-9; manure and lime on corn only.										
19	....	....	....	....	....	....	....	....	....	....	....
20	Untreated shed manure 10 tons, 1903-4-5; lime 1,000 lbs., 1906-7-8; manure and lime on wheat only										
21	Lime, 1,000 lbs. on corn; untreated shed manure, 5 tons on wheat.										
22	Unfertilized.										
23	Untreated yard manure, 5 tons, on corn only.										
24	Untreated shed manure, 5 tons, on corn only.										
25	Unfertilized.										
26	Phosphated yard manure, 5 tons on corn only.										
27	Phosphated shed manure, 5 tons on corn only.										
28	Unfertilized.										
29	Phosphated shed manure, 5 tons on corn; lime, 1000 lbs. on wheat.										
30	Tankage, 680 lbs; muriate of potash, 80 lbs; nitrate of soda, 80 lbs. on corn; lime, 1,000 lbs. on wheat.										
31	Unfertilized.										
32	Tankage, 340 lbs; muriate of potash, 40 lbs; nitrate of soda, 40 lbs; on corn; same on wheat.										
33	Tankage, 340 lbs; muriate of potash, 60 lbs; nitrate of soda, 120 lbs. on corn; same on wheat.										
34	Unfertilized.										
35	Tankage, 220 lbs; acid phos., 200 lbs; muriate of potash, 20 lbs. on corn; same on wheat.										
36	Tankage, 220 lbs; acid phos., 200 lbs; muriate of potash, 40 lbs; nitrate of soda, 80 lbs. on corn; same on wheat.										
37	Unfertilized.										
38	Tankage, 500 lbs; muriate of potash, 60 lbs; nitrate of soda, 60 lbs. on corn; same on wheat.										
39	Tankage, 170 lbs; nitrate of soda, 18 lbs. on corn; same on wheat,										
40	Unfertilized.										

Table XI shows that acid phosphate, when used alone at the rate of 120 pounds per acre each on corn and wheat, has produced a profitable increase in each crop, as well as in the clover following, the total value of the increase amounting to more than 4 times the cost of the fertilizer.

When the very small quantity of 20 pounds per acre of muriate of potash is added to this dressing of acid phosphate the total and net gain are largely increased, and that this increase is not due to accidental variations in the soil is indicated by comparing Plot 6, which receives nitrate of soda and acid phosphate, but no potash, with Plot 8, which receives the same quantities of nitrate of soda and acid phosphate, with 20 pounds of muriate of potash in addition. It seems evident, therefore, that both phosphorus and potassium are needed in the fertilizer to produce the best results on this soil.

DIAGRAM III: ARRANGEMENT OF PLOTS IN CORN-WHEAT-CLOVER ROTATION



Plots are numbered from left to right in each section. Dotted lines indicate tile drains.

That nitrogen also is needed is seen by comparing Plot 6, receiving nitrogen and phosphorus, with Plot 2, receiving phosphorus only; or by comparing Plot 8, receiving nitrogen, phosphorus and potassium, with Plot 3, receiving phosphorus and potassium only. It is true that the net gain is not as large on Plot 8 as on Plot 3, owing to the high cost of fertilizer nitrogen; but when we increase the proportion of phosphorus to nitrogen, on Plot 12, we get a larger net gain than on any other combination of fertilizing materials used in the experiment. It is true that a somewhat larger total increase has been secured on Plots 14 and 33, receiving more nitrogen, but the extra cost of the fertilizer has outrun the value of the increase on these plots.

TABLE X: CORN-WHEAT-CLOVER ROTATION:—STATISTICS OF YIELD FOR 1907 AND 1908.

Plot	Corn				Wheat				Clover	
	Grain		Stover		Grain		Straw		Hay	
	1907	1908	1907	1908	1907	1908	1907	1908	1907	1908
No.	Bus.	Bus.	Lbs.	Lbs.	Bus.	Bus.	Lbs.	Lbs.	Lbs.	Lbs.
1	58.14	28.57	3,100	2,400	12.33	9.83	1,330	1,720	2,310	1,470
2	65 71	33.14	3,410	2,580	15.08	14.42	1,625	2,375	2,750	2,290
3	73.43	42.14	3,900	2,990	20.50	15.00	2,210	2,510	3,110	2,480
4	59.71	32.43	3,190	2,410	14.18	12.83	1,529	2,110	2,900	1,550
5	61.29	39.14	3,410	2,710	15.08	12.87	1,625	2,217	2,820	1,620
6	60.29	40.14	3,210	2,900	19.79	15.79	2,133	2,762	3,550	2,300
7	46.86	40.57	2,600	2,750	11.32	10.12	1,221	1,782	3,160	1,390
8	63.57	52.43	3,540	3,080	21.16	15.08	2,280	2,665	3,350	2,430
9	66.86	55.57	3,680	3,280	21.21	15.79	2,287	2,792	3,190	2,350
10	44.57	49.71	2,760	2,950	11.44	10.70	1,234	1,685	3,240	1,290
11	80.71	61.86	4,580	3,620	21.99	17.17	2,371	2,840	3,820	2,520
12	77.71	66.00	4,800	3,780	23.95	17.00	2,583	2,630	3,780	3,860
13	63.86	52 00	3,630	3,240	13.64	10.92	1,472	1,645	3,030	1,390
14	81.86	63 71	5,120	3,800	25.03	18.04	2,698	2,967	3,750	4,100
15	84.00	52.43	5,770	3,850	21.81	14.83	2,351	2,240	3,780	2,630
16	50.43	39.71	3,170	2,550	13 94	9.17	1,504	1,390	2,670	1,670
17	70.71	56.14	4,700	3,720	19.43	12.83	2,094	2,080	3,960	2,760
18	71.57	50.00	4,790	3,300	19.07	11.04	2,056	1,857	3,820	2,330
19	60.86	46.14	3,850	2,920	14.84	10.37	1,600	1,557	3,270	1,630
20	70.29	44.57	4,410	2,750	21.69	10.21	2,339	1,687	3,770	2,990
21	60.29	38.14	3,560	2,550	23.30	12.96	2,512	2,152	3,440	3,090
22	45.71	35.86	2,900	2,460	15.14	7.21	1,632	1,267	3,160	1,760
23	53.43	41 00	3,110	2,420	18.42	8.21	1,985	1,437	3,760	2,060
24	61.71	46.71	3,650	2,720	20.08	10.62	2,165	1,792	4,070	2,140
25	37.57	32.29	2,510	2,280	13.82	6.21	1,491	1,267	3,010	1,800
26	60.43	41.71	3,350	2,700	18.59	13.00	2,005	2,190	3,350	1,920
27	75.00	49.00	4,250	2,660	16.51	13.04	1,779	1,967	3,590	2,130
28	68.57	40.00	3,690	2,530	10.91	7.67	1,175	1,510	3,030	1,520
29	81.00	47.29	5,100	3,100	18.30	15.29	1,972	2,392	3,780	2,460
30	81.71	58.00	5,010	3,450	22.47	12.17	2,422	2,250	4,170	3,390
31	51.71	41.86	3,050	2,610	17.34	7.17	1,869	1,530	3,320	2,490
32	63.14	56.29	3,360	3,360	29.38	14.17	3,167	2,670	4,120	4,750
33	66.86	53.29	4,150	3,290	31.23	15.54	3,366	2,967	4,230	4,800
34	33.43	33.71	2,250	2,520	21.93	5.17	2,364	1,160	2,830	3,700
35	59.29	47.71	3,450	2,790	29.92	14.50	3,225	2,480	3,600	5,600
36	64.43	45 71	3,780	2,690	29.50	15.37	3,180	2,657	3,590	5,470
37	48.43	26.86	2,900	2,560	21.21	4.58	2,287	825	2,090	3,850
38	66.14	44 57	4,330	2,960	26.46	11.83	2,852	1,890	3,800	5,270
39	60.43	27 43	3,600	1,950	18.95	6.75	2,043	1,155	2,350	3,610
40	59.71	25.29	4,100	1,830	14.66	4.42	1,580	835	1,880	2,050
*	52.11	37.50	3 121	2 501	14.84	8.31	1 592	1 449	2 850	1 969

*Average unfertilized yield.

TABLE XI: CORN-WHEAT-CLOVER ROTATION: AVERAGE INCREASE, COST OF FERTILIZERS AND NET GAIN PER ACRE, 1905 to 1908.

Plot	Fertilizing elements per acre			Average increase per acre					Cost of fertilizers	Value of increase	Net Gain	Plot
	Phosphorus	Potassium	Nitrogen	Corn: 5-year av.		Wheat: 4-year av.		Clover 4-yr. av.				
				Grain	Stover	Grain	Straw.					
No.	Lbs.	Lbs.	Lbs.	Bus.	Lbs.	Bus.	Lbs.	Lbs.	$	$	$	No.
2	15	....	....	7.28	213	4.54	447	453	1.90	9.12	7.22	2
3	15	16½	...	11.31	494	5.90	614	657	2.90	13.23	10.33	3
5	..	16½	25⅓	4.43	247	1.27	166	244	5.80	4.30	—1.50	5
6	15	....	25⅓	7.76	313	6.89	724	711	6.70	12.65	5.95	6
8	15	16½	25⅓	12.21	479	7.65	849	736	7.70	15.51	7.81	8
9	15	16½	50⅔	10.99	373	7.89	944	556	12.50	14.43	1.93	9
11	15	33	25⅓	16.21	872	9.71	1,137	942	13.50	20.46	6.96	11
12	30	16½	25⅓	15.99	850	10.43	1,165	1,328	9.60	22.49	12.89	12
14	30	33	50⅔	17.37	862	12.61	1,464	1,090	15.40	24.15	8.75	14
15	30	33	50⅔	18.34	1,336	6.52	736	707	17.90	18.18	.28	15
17	..	....	....	16.91	1,013	4.28	500	744	.....	15.18	.....	17
18	..	....	....	13.13	905	5.03	576	566	.....	13.47	.. ...	18
20	..	....	....	13.03	621	5.07	552	1,027	.....	14.86	.....	20
21	..	....	....	2.05	—14	3.34	414	823	.....	7.18	.....	21
23	..	....	....	12.78	413	1.67	163	286	.....	8.37	.....	23
24	..	....	....	19.16	701	5.15	535	461	.....	15 21	.....	24
26	..	....	....	11.66	395	4.07	462	145	.....	9 55	.....	26
27	..	....	...	13.23	525	3.52	330	189	.....	9.98	.....	27
29	..	....	....	13.67	944	5.11	570	484	.....	13.48	.....	29
30	30	33	50⅔	15.88	1,043	6.35	658	779	17.90	16.77	1.13	30
32	30	33	50⅔	14.33	601	9.92	1,087	1,144	15.40	20.23	4.83	32
33	30	50	76	15.76	916	11.47	1,294	1,118	21.20	22.62	1.42	33
35	44	16½	25⅓	13.77	579	8.96	1,017	1,161	11.50	19.20	7.70	35
36	44	33	50⅔	13.60	599	11.03	1,263	1,059	17.30	20.66	3.36	36
38	44	50	76	14.15	799	10.15	1,093	1,116	22.10	20.53	—1.57	38
39	15	....	25⅓	3.36	—33	2.34	248	283	6.70	4.55	2.15	39
Average unfertilized yield.....				45.84	2,648	10.7	1,316					

Plot 12 receives 160 pounds of nitrate of soda, carrying about 25 1-3 pounds of nitrogen, equivalent to 30 pounds of "ammonia;"* 480 pounds of 14 percent acid phosphate, carrying 30 pounds of phosphorus or 68 pounds of "phosphoric acid," and 40 pounds of muriate of potash, carrying 16 1-2 pounds of potassium or 20 pounds of "potash."

As fertilizers are ordinarily computed the percentage composition of this mixture would be approximately as below:

Carrier	Pounds of essential constituents		
	Ammonia	Phosphoric Acid	Potash
160 lbs. nitrate of soda	30	...	...
480 lbs. acid phosphate	...	68	...
40 lbs. muriate of potash	...	...	20
680 lbs. total	30	68	20
Percentage	4	10	3

Five tons of fresh manure, as used on Plot 24, should contain approximately the same quantities of nitrogen and phosphorus and about twice as much potassium as have been used on Plot 9. Comparing Plots 24 and 9 we see that the corn has made a larger increase on Plot 24 and the wheat and clover on Plot 9, the total value of the increase being slightly greater on Plot 24. Had Plot 24 received the same chemical fertilizers as Plot 9, but all in one application to the corn crop, the result would undoubtedly have been a larger increase in that crop and a smaller one in the wheat and clover, with probably a smaller total increase on all the crops (compare Plots 14 and 15, Table XI.) Hence it is fair to conclude that the chemical constituents of the fresh manure are producing practically the same effect as those in the chemicals. The results attained on the manured plots as a whole, however, are as yet inconclusive. The shed manure has been followed by a greater average increase than the yard manure, but the untreated manure has apparently produced a larger increase than that reenforced with floats, whether we compare Plot 17 with 29 or Plots 23 and 24 with 26 and 27. A careful analysis of the results, however, indicates that this outcome is largely due to inequalities in soil conditions which will probably be eliminated, in part at least, as the work progresses. It will be remembered that in these experiments there are as many separate tracts or sections of land as there

*Ammonia is a compound of nitrogen with hydrogen, containing about 82 percent nitrogen; phosphoric acid is a compound of phosphorus with oxygen, containing about 44 percent phosphorus, and potash is a compound of potassium with oxygen, containing nearly 84 percent potassium.

are crops in the rotation. In the one under consideration the corn crop, grown on Section A in 1904, yielded 30.14 bushels per acre for the untreated manure and 32.28 bushels for the phosphated manure. In 1907 the yields on the same land were 57.57 and 68.57 bushels, respectively, for the treated and untreated manure. In 1905 the yields on Section B were 72.00 for untreated and 62.78 for phosphated manure; but in 1908 the yields were 43.85 and 45.35 bushels, respectively, a reversal in both cases of more than 10 bushels per acre in the respective yields. Wheat was grown on Section A in 1905, and the yields, like those of the previous corn crop, were practically the same for the two kinds of manure; but in 1908 the yield for the phosphated manure was nearly 40 percent greater than for that not so treated.

These points illustrate the importance of long continued work on a systematic plan in dealing with such problems as this. On the one hand we have a soil which has been under cultivation for nearly a century and which has probably been subjected to differences in treatment of which we can have no knowledge, and on the other we have a fertilizing substance (floats) notoriously inert and slow in action.

This comparison is being duplicated in the tobacco rotation on the same farm, and here the results are consistent with those attained in the larger test at the main station, where the advantage of reenforcing farm manures with phosphorus is being strikingly demonstrated,* although in this test also the differences shown at the beginning of the work were much smaller than they have grown to be as the work has progressed.

On plots 30 to 39, inclusive, a part or all of the nitrogen and phosphorus is given in tankage, instead of nitrate of soda and acid phosphate. Comparing these with the plots receiving all their nitrogen and phosphorus in nitrate of soda and acid phosphate, it will be seen that tankage has not proved to be as effective a carrier as the other materials. This is a matter of considerable importance to the farmer, since the nitrogen in the ordinary, ready-mixed commercial fertilizer is derived chiefly from tankage.† In computing the cost of the fertilizer the tankage nitrogen is computed at the same price as that in nitrate of soda. In point of fact, the farmer usually pays more for the nitrogen carried in ready-mixed fertilizers than he would need to pay for it in nitrate of soda.

*See Circular 92. p. 25.

†The nitrogen in tankage is in organic form, and must be first converted into ammonia and then into nitric acid before it becomes available. The nitrogen of fresh manure is largely in the form of ammonia, hence it is well on the way towards availability.

It is interesting now to compare the outcome of the first 5 years' work at Germantown with that in the similar experiment at the main station at Wooster for the three 5-year periods over which it has been conducted, as summarized on page 16 of Circular 92. As the experiment at Wooster is a 5-year rotation and that at Germanton is one of 3 years it will be necessary to make the comparison on the basis of the annual value of increase and cost of fertilizer.

TABLE XII, COMPARISON OF RESULTS AT GERMANTOWN AND WOOSTER.

Fertilizing elements	Germantown			Wooster				
	Plot No	Annual cost of fertilizer	Annual value of increase	Plot No.	Annual cost of fertilizer	Annual value of increase		
						First 5 years	Second 5 years	Third 5 years
Phosphorus alone	2	$ 0.63	$ 3 04	2	$ 0 52	$1 70	$ 3.47	$4 86
Phosphorus and potassium	3	0.97	4.41	8	1.82	2.88	4.87	6 70
Phosphorus, potassium and nitrogen	8	2 57	5.17	11	4.70	5.28	8.49	9.99
" " " "	12	3 20	7 50	17	3.87	3 15	7.32	9.26

Table XII shows that the results attained thus far at Germantown, in proportion to quantity of fertilizers, are considerably greater than those reached during the first 5-year period at Wooster. Whether there will be the cumulative effect at Germantown that has been experienced at Wooster remains for the future to determine.

GENERAL CONSIDERATIONS.

The course of agriculture in the Miami Valley has been one of systematic soil exhaustion. Grain crops, timothy and tobacco have been grown continuously or with only occasional short turns in clover; the corn has been sold to the elevators or to the distillers or fed to hogs; the wheat has gone into the general market and the timothy has been sent to the cities. But little manure has been made and that little has largely been wasted. Some restitution has been made to the soil in places by overflow, but more often the overflows have carried away more fertility than they have left. The outcome of this system is that the yield of corn, which during the 20 years, 1850-69, averaged 37.5 bushels per acre for the 5 counties, Montgomery, Preble, Butler, Warren and Hamilton, fell to 34.7 for the 20 years, 1880-99. During the same two periods the yield of wheat was 13.6 bushels for the first period and 14.1 bushels for the second, an increase of half a bushel per acre

Taking the 13 counties comprised in the two tiers lying north of those named, the yields for these two periods have been for corn, 30.1 bushels and 34.6 bushels, and for wheat, 11.7 bushels and 14.4 bushels, a gain of 4.5 bushels of corn and 2.7 bushels of wheat. These counties are now equalling the yields of the Miami Valley in corn and are exceeding their yields in wheat, and the richest region of the state has shifted from this fertile valley to the northwestern counties.

In the ripening of the grain crops about three-fourths of the total phosphorus of the plant is carried into the grain, while about three-fourths of the potassium remains in the straw. Consequently in all regions where grain is largely produced and sold off the farm ordinary soils soon show a deficiency of phosphorus, while in those regions in which not only the grain, but also the straw and hay are removed, both phosphorus and potassium are likely to be exhausted, and this condition applies to the lower Miami Valley; the paper mills and the tobacco warehouses, together with the urgent city demand for hay, having stripped the land of everything that could be carried away except the corn stalks, and that they were not also taken was only due to the fortunate circumstance that they were not adapted to paper making.

Under such conditions it is to be expected that potassium will occupy a position of larger relative importance in the fertilizer than for a region in which the system of agriculture has involved the deportation of grain and animal products chiefly, the straw and hay being retained on the land, and that it will be necessary to restore this element, as well as nitrogen and phosphorus, before maximum yields can be attained.

CONCLUSIONS.

These experiments must be carried much further before final conclusions can safely be drawn, but they have already demonstrated that the yield of crops may be greatly and profitably increased, on the upland soils of the Miami Valley, by the judicious use of manure or chemical fertilizers.

They show that the most effective manure is that which has not been subjected to the losses which occur in the open barnyard, and they indicate that the most effective fertilizer is one containing nitrogen, phosphorus and potassium, all three.

No urgent need of lime has as yet been developed in the soil under these experiments, and this was to be expected from its geological history. It has not yet been demonstrated, however, that moderate applications of lime may not be useful, especially upon those fields in this region which have been longest under cultivation.